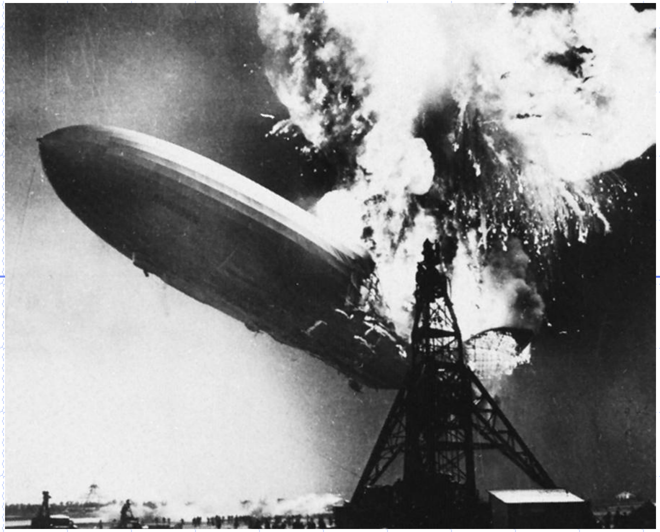
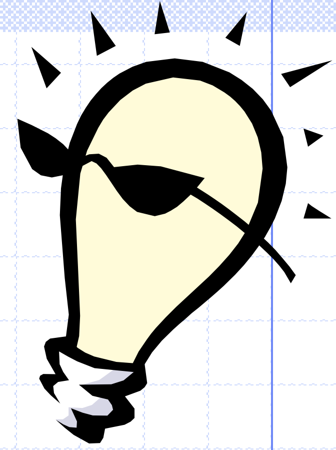


TOPIC 05 – ENERGETICS
THERMOCHEM: HEAT CHANGE

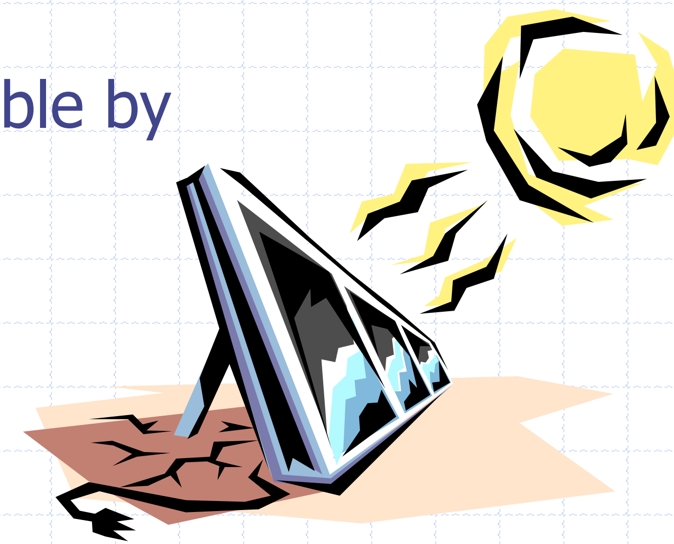
IB Chemistry

T05D01



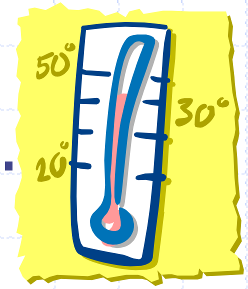
Energy **is the capacity to do work**

- ***Thermal energy*** is the energy associated with the random motion of atoms and molecules
- ***Chemical energy*** is the energy stored within the bonds of chemical substances
- ***Nuclear energy*** is the energy stored within the collection of neutrons and protons in the atom
- ***Electrical energy*** is the energy associated with the flow of electrons
- ***Potential energy*** is the energy available by virtue of an object's position



Energy Changes in Chemical Reactions

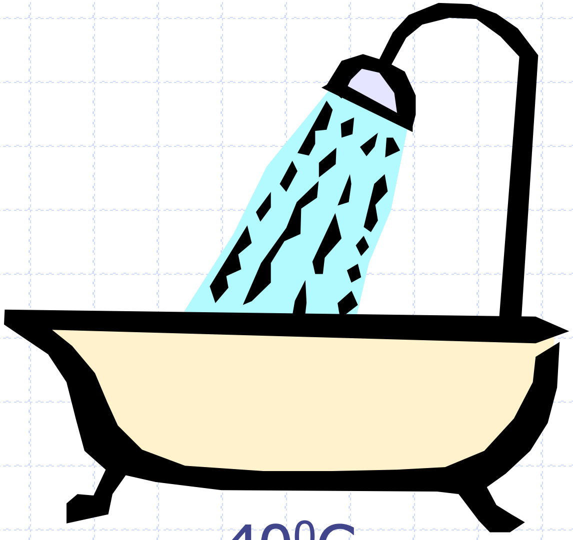
Heat is the transfer of **thermal energy** between two bodies that are at different temperatures.



Temperature is a measure of the thermal energy.

Temperature ≠ Thermal Energy

90^{0}C



40^{0}C

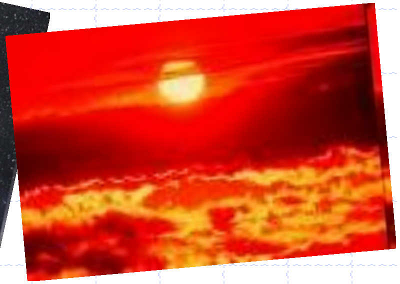
greater thermal energy
(since the mass is larger)

Heat and Temperature

- Heat is energy that is transferred from one object to another due to a difference in temperature
- Temperature is a measure of the average kinetic energy of a body
- Heat is always transferred from objects at a higher temperature to those at a lower temperature

Factors Affecting Heat Quantities

- The amount of heat contained by an object depends primarily on three factors:
  - The mass (m) of material
  - The temperature (t)
  - The kind of material and its ability to absorb or retain heat (s) or (C).



Heat Quantities

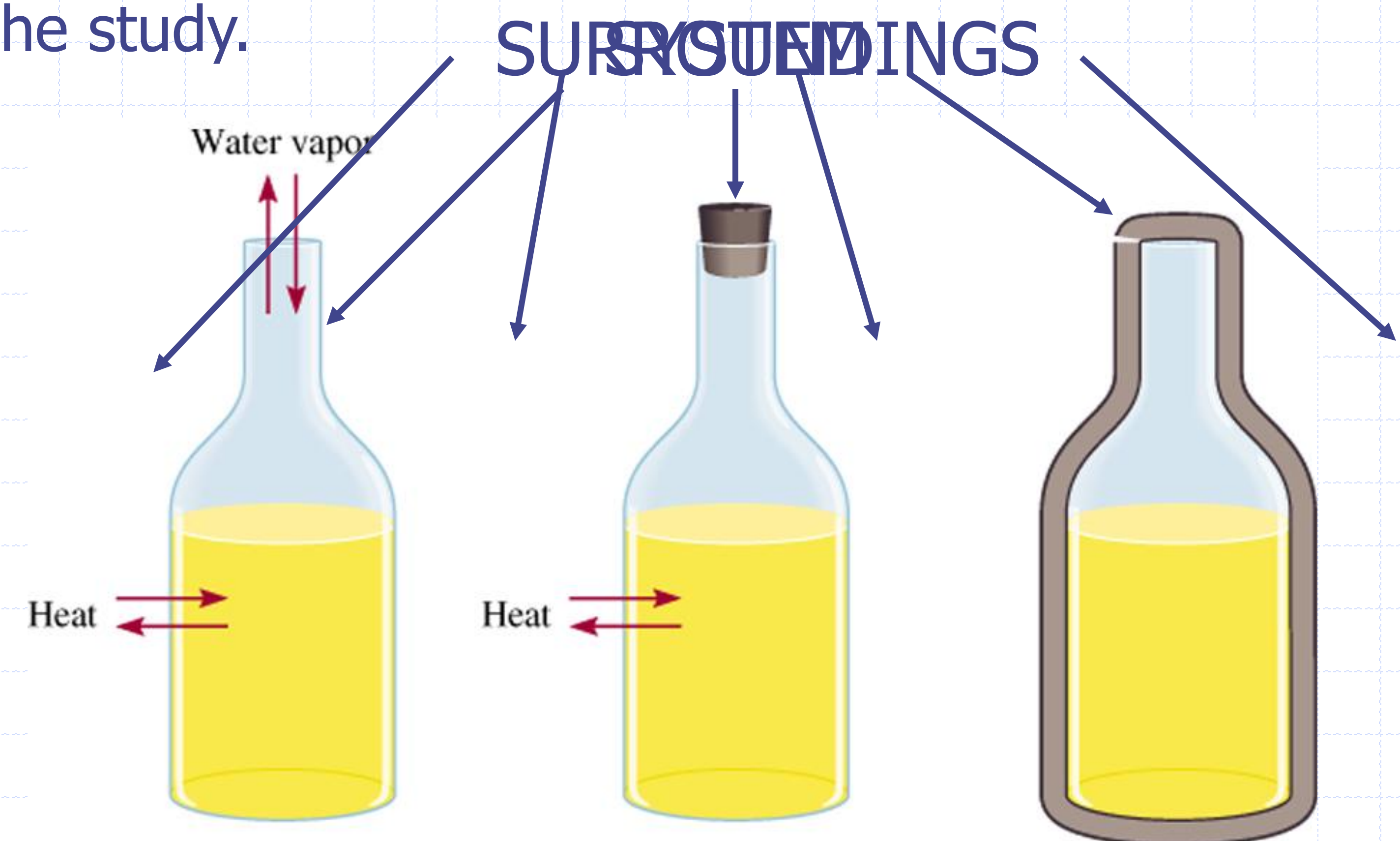
- The heat required to raise the temperature of 1.00 g of water 1 ^{o}C is known as a calorie.
- The SI unit for heat is the joule. It is based on the mechanical energy requirements.
- 1.00 calorie = 4.184 Joules
- The energy required to raise 1 pound of water of 1 ^{o}F is called a British Thermal Unit or BTU
- The BTU is widely used in the USA to compute energy capacities of heating and air conditioning equipment

Calorimetry

- Calorimetry involves the measurement of heat changes that occur in chemical processes or reactions.
- The heat change that occurs when a substance absorbs or releases energy is really a function of three quantities:
  - The mass
  - The temperature change
  - The heat capacity of the material

Thermochemistry is the study of heat change in chemical reactions.

The ***system*** is the specific part of the universe that is of interest in the study.



	open	closed	isolated
Exchange:	mass & energy	energy	nothing

Movement of Thermal Energy

Exothermic process is any process that gives off heat – transfers thermal energy from the system to the surroundings.

$$2H_2\,(g) + O_2\,(g) \longrightarrow 2H_2O\,(l) + \text{energy}$$

$$H_2O\,(g) \longrightarrow H_2O\,(l) + \text{energy}$$

Endothermic process is any process in which heat has to be supplied to the system from the surroundings. Takes in heat.

$$\text{energy} + 2HgO\,(s) \longrightarrow 2Hg\,(l) + O_2\,(g)$$

$$\text{energy} + H_2O\,(s) \longrightarrow H_2O\,(l)$$

Equations for Heat Change (q)

The ***specific heat*** (***s***) of a substance is the amount of **heat (*q*)** required to raise the temperature of **one gram** of the substance by **one degree** Celsius.

The ***heat capacity*** (***C***) of a substance is the amount of **heat (*q*)** required to raise the temperature of a given quantity in **mass (*m*)** of the substance by **one degree** Celsius.

$$C = ms$$

Table 6.1 The Specific Heats of Some Common Substances

Substance	Specific heat (J/g · °C)
Al	0.900
Au	0.129
C (graphite)	0.720
C (diamond)	0.502
Cu	0.385
Fe	0.444
Hg	0.139
H_2O	4.184
C_2H_5OH (ethanol)	2.46

Heat (*q*) absorbed or released:

$$q = ms\Delta t$$

$$q = C\Delta t$$

$$\Delta t = t_{final} - t_{initial}$$

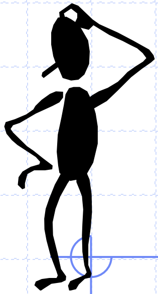
Specific Heat values for Some Common Substances

Substance	C J g^{-1} K^{-1}	C J mol^{-1}K^{-1}
Water (liquid)	**4.184**	75.327
Water (steam)	2.080	37.47
Water (ice)	2.050	38.09
Copper	0.385	24.47
Aluminum	0.897	24.2
Ethanol	2.44	112
Lead	0.127	26.4

Variables for Heat Change:

- **q**, is the **heat change** within the system
- **s**, is the **specific heat** of the substance
  - Does not take into account the mass
  - Use the equation $q = ms\,\Delta T$
- **C**, is the **heat capacity** of the substance
  - Takes into account the mass
  - Use the equation $q = C\,\Delta T$
- **m**, is the **mass** of the substance
- **ΔT**, is the **change in temperature**
  - $\mathbf{\Delta T = T_f - T_i}$

Heat Change Example:



Example: How much heat is given off when an 869 g iron bar cools from 94^0C to 5^0C? The specific heat of Fe is 0.444 J/g • ^{0}C

s of Fe = 0.444 J/g • ^{0}C

m of Fe = 869 g

$\Delta t = t_f - t_i$
= 5^0c – 94^0c
= -89^0C

$q = ms\Delta t$ = 869 g x 0.444 J/g • ^{0}C x –89^0C

= -34,000 J

We know the Fe cools (stated above) and the value given is -34 kJ, what does the negative value tell us? Is this an endo- or exo-thermic process?

Enthalpy (H)

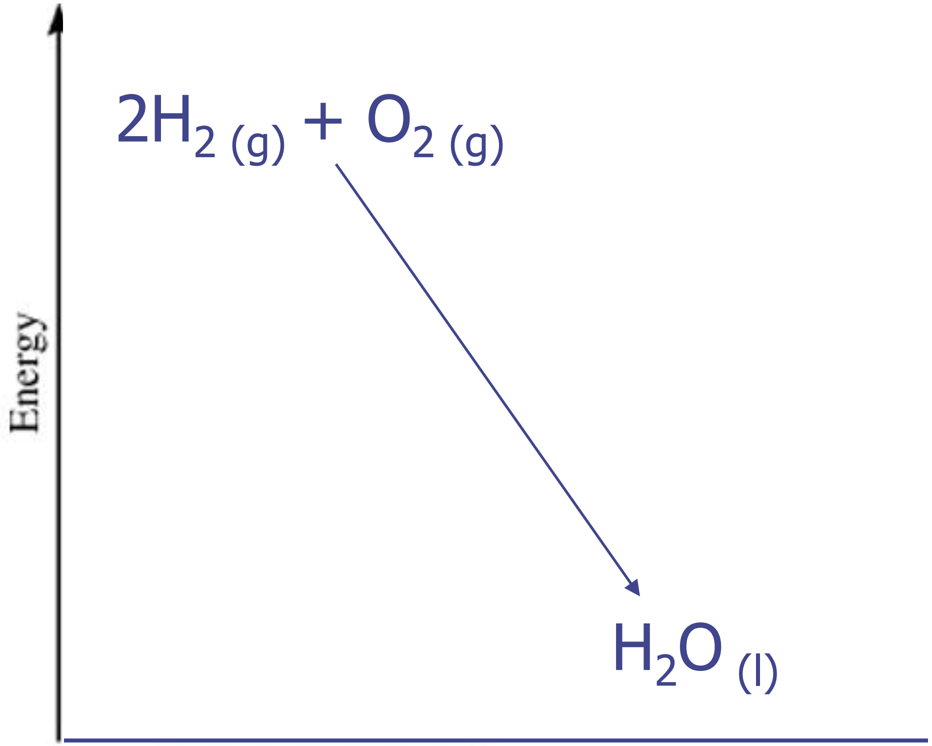
Enthalpy (H) is used to quantify the heat flow into or out of a system in a process that occurs at constant pressure. ***Can be equated with q***. *(q is generally in J and H in kJ)*

$\Delta H =$ heat given off or absorbed during a reaction **at constant pressure**

$$\Delta H = H\text{(products)} - H\text{(reactants)}$$

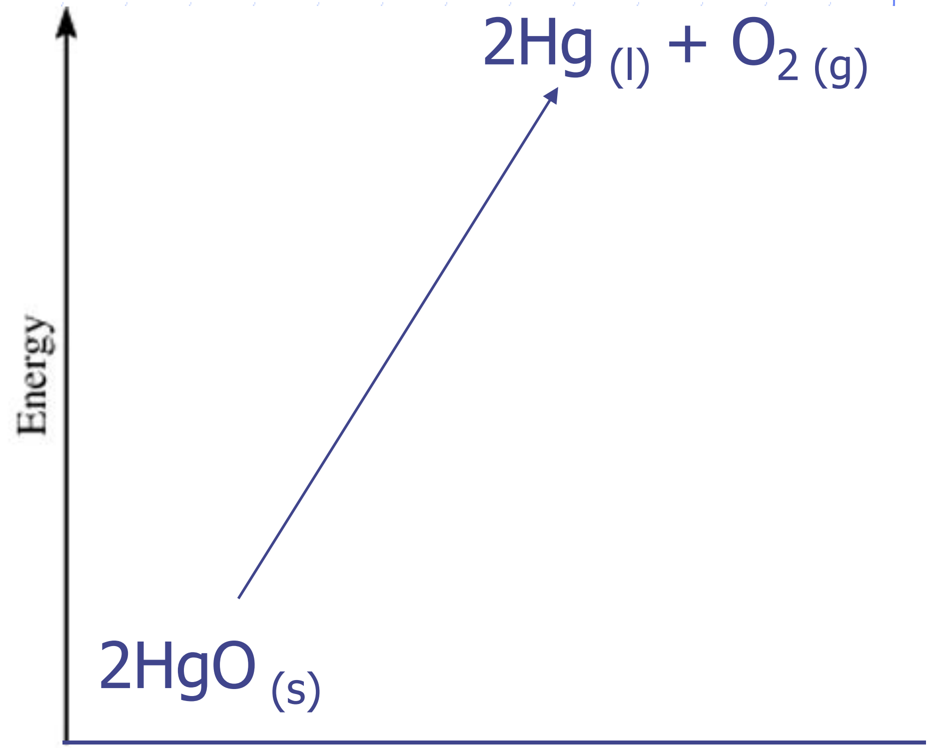
Enthalpy (H)

$$\Delta H = H\,(\text{products}) - H\,(\text{reactants})$$



$H_{products} < H_{reactants}$

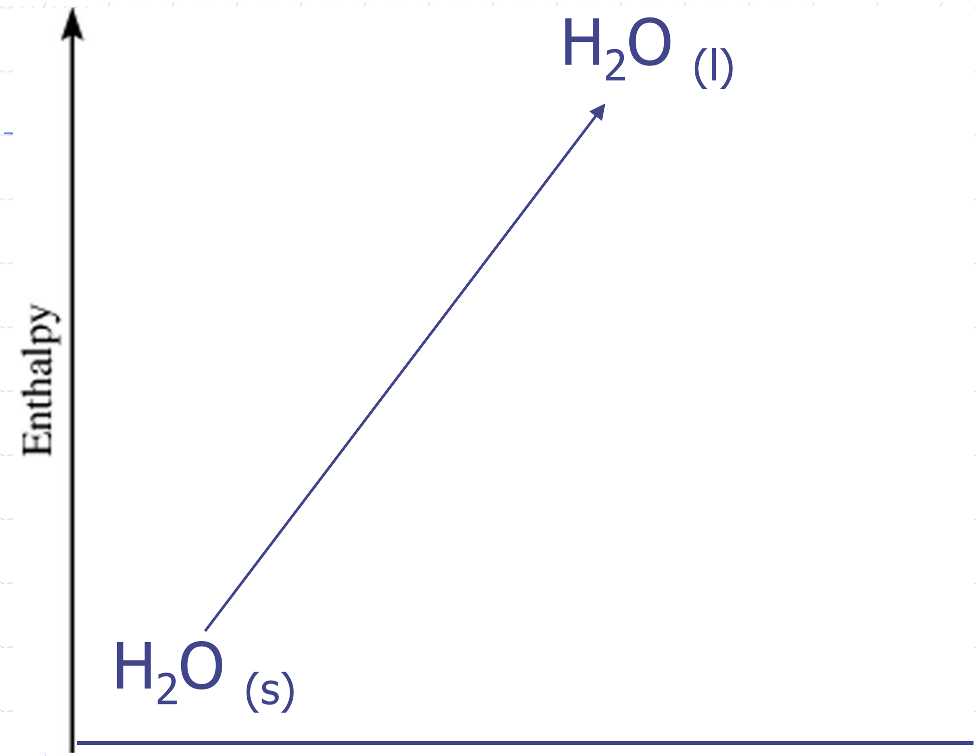
$\Delta H < 0$ (exothermic)



$H_{products} > H_{reactants}$

$\Delta H > 0$ (endothermic)

Enthalpy: Thermochemical Equations



Is ΔH negative or positive?

System absorbs heat

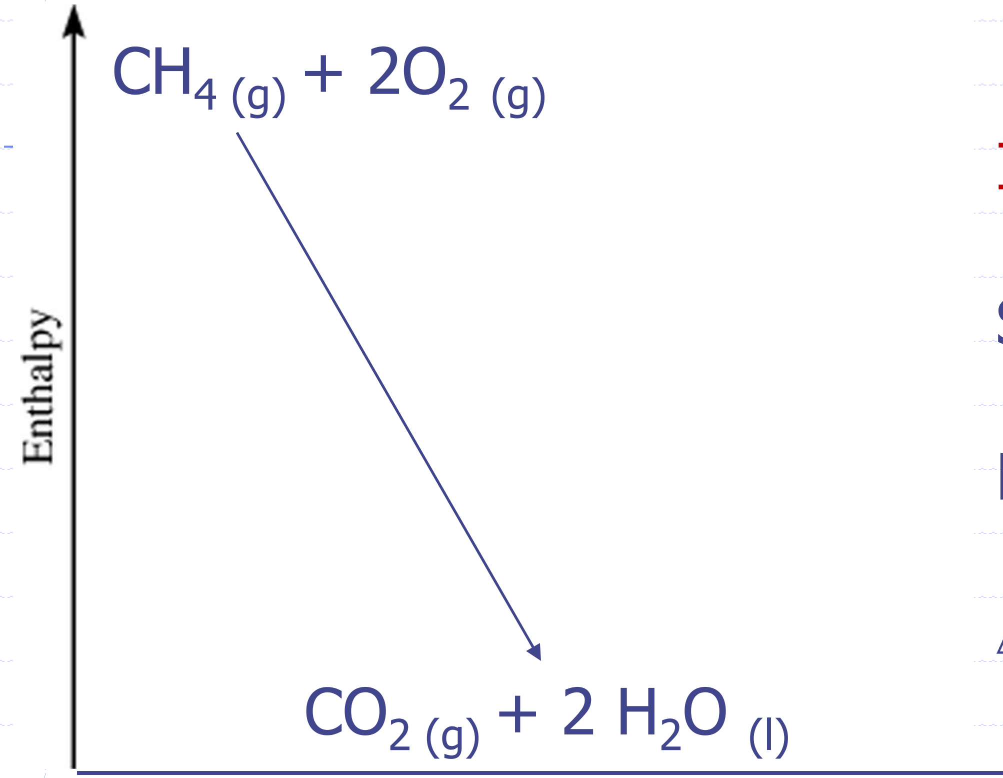
Endothermic

$\Delta H > 0$

6.01 kJ are absorbed for every 1 mole of ice that melts at 0^0C and 1 atm.

$$H_2O\ (s) \longrightarrow H_2O\ (l) \quad \Delta H = 6.01\ \text{kJ}$$

Enthalpy: Thermochemical Equations



Is ΔH negative or positive?

System gives off heat

Exothermic

$\Delta H < 0$

890.4 kJ are released for every 1 mole of methane that is combusted at 25^0C and 1 atm.

$$CH_4\,(g) + 2O_2\,(g) \longrightarrow CO_2\,(g) + 2H_2O\,(l) \quad \Delta H = -890.4\ \text{kJ}$$

Enthalpy: Thermochemical Equations

- The stoichiometric coefficients always refer to the number of moles of a substance

$$H_2O\ (s) \longrightarrow H_2O\ (l) \qquad \Delta H = 6.01\ \text{kJ}$$

- If you reverse a reaction, the sign of ΔH changes

$$H_2O\ (l) \longrightarrow H_2O\ (s) \qquad \Delta H = -6.01\ \text{kJ}$$

- If you multiply both sides of the equation by a factor *n*, then ΔH must change by the same factor *n*.

$$2H_2O\ (s) \longrightarrow 2H_2O\ (l) \qquad \Delta H = 2 \times 6.01 = 12.0\ \text{kJ}$$

Energy lost = Energy Gained

- You needed to calculate q (heat change) for NaOH and $Na_2S_2O_3$. Lets use NaOH as our example:
  - q_{NaOH} cannot be found directly, but q_{H2O} can be
  - $q_{NaOH} = -(q_{H2O})$ (this is the conservation of energy)
  - $q_{H2O} = ms\Delta T$
    - m = 50.00 g
    - s = 4.184 J/g°c
    - ΔT =20.00 °c
  - q_{H2O} = (50.00 ~~g~~)(4.184 J/~~g°c~~)(20.00~~°c~~)
  - q_{H2O} = 4,184 J
  - q_{NaOH} = -4,184 J
- Now, how many grams of NaOH were used to produce this amount of heat? (for my data it was 1.24 g NaOH)

First Law of Thermodynamics!

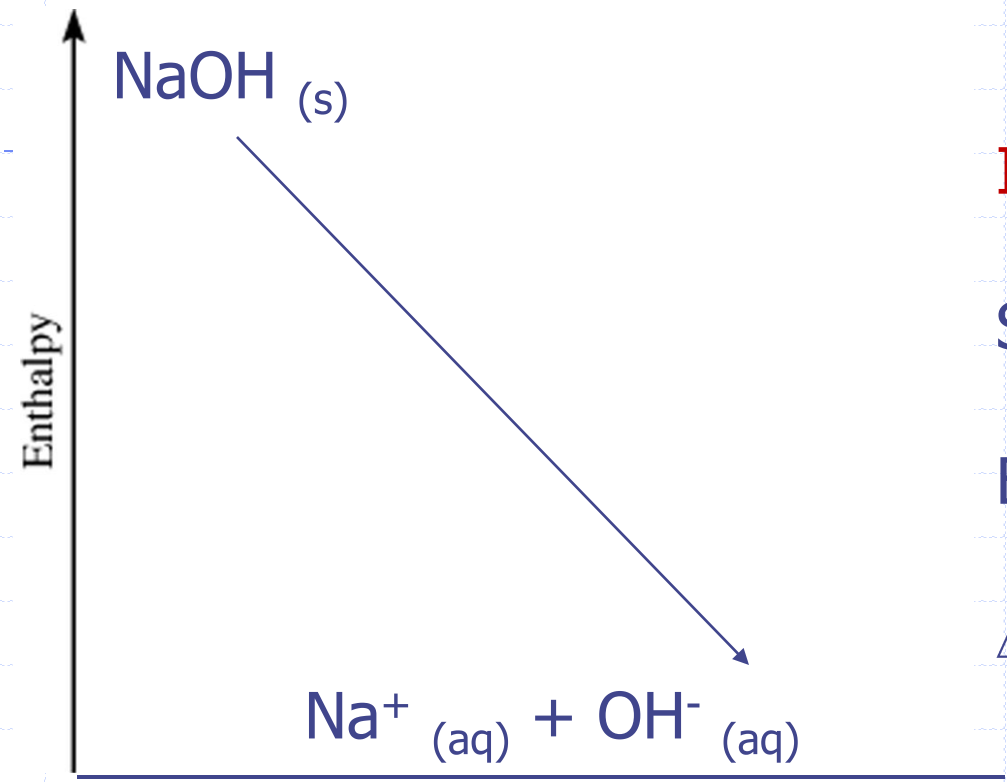
Energy lost = Energy gained

q = -q

Calculate Molar Heat of Solution

- In my reaction example, with 1.24 g NaOH I produced a value of q_{NaOH} = -4,184 J
- So, lets write this in units of Joules per gram
  - q_{NaOH} = ____________
- You need to find Joules per mole (molar heats of solution) so that you can relate to the heat production of the other salt.
  - __________ ___________ ___
  - **$NaOH(s) \rightarrow Na^{+}(aq) + OH^{-}(aq)$ q_{NaOH} = -134 kJ/mol**
  - $Na_2S_2O_3(s) \rightarrow 2\ Na^{+}(aq) + S_2O_3^{2-}(aq)$ $q_{Na2S2O3}$ = + or - ??

Enthalpy: Thermochemical Equations



Is ΔH negative or positive?

System gives off heat

Exothermic

$\Delta H < 0$

134 kJ are released for every 1 mole of sodium hydroxide that is dissolved into water.

$NaOH(s) \rightarrow Na^{+}(aq) + OH^{-}(aq)$

q_{NaOH} = -134 kJ/mol

ΔH = -134 kJ/mol